Space Technology Research Grants

Detectors for Measurements of the Cosmic Microwave Background Radiation

Completed Technology Project (2012 - 2016)

Project Introduction

Inflation theory predicts gravity waves in the early universe. These gravity waves are caused by tensor fluctuations, which we expect to have left an imprint in the form of B-mode polarization anisotropies in the CMB. Detecting this polarization is key to confirming and constraining inflation theory as well as a number of cosmological parameters. However, it is very challenging to make such a measurement because the tensor to scalar ratio is expected to be small, especially at large angular scales. In order to achieve the required sensitivity, a new generation of instruments with low-noise, high pixel-count arrays is required. One such instrument is the Q&U Bolometric Interferometer for Cosmology (QUBIC), a novel ground-based telescope planned for deployment at the Concordia station in Antarctica in 2013. QUBIC will also forge a technological path for a future space-based mission such as CMBPol. I propose to develop a detector array optimized for the QUBIC instrument. There are two types of detectors that we believe are the most promising candidates: transition edge sensors (TESs) and microwave kinetic inductance detectors (MKIDs), each having advantages and disadvantages in relation to the QUBIC goals. As the current standard for CMB detector arrays, TESs are an extremely well-understood and thoroughly field-tested technology. Though often regarded as photon noise-limited devices, careful calculation reveals that under reasonable QUBIC conditions, we can expect the total NEP (photon+ thermal noise added in quadrature) to be ~ 70% greater than the photon NEP limit. Though TESs have the advantage of being highly sensitive and well-understood, they have a few notable disadvantages in terms of their applicability to the QUBIC telescope. Thermal isolation requirements demand micromachined membranes, which significantly increase fabrication complexity and limit focal plane coverage. Additionally, as arrays push into the multi-thousands of pixels in an effort to achieve the sensitivity needed to detect or rule out the B-mode anisotropy, the technical complexity of SQUID multiplexing schemes is becoming increasingly daunting. The other main candidate for the QUBIC detector array is MKIDs. MKIDs have a number of advantages. Most notably, they lend themselves elegantly to passive frequency domain multiplexing, allowing up to ~1000 pixels to be read out with a single transmission line and a single HEMT amplifier. Additionally, since MKIDs do not have the thermal isolation requirements of bolometers, MKIDs can achieve better focal plane coverage. MKIDs do, however, have certain challenges associated with them. There is in addition to the usual photon noise, a contribution resulting from the generation and recombination of quasiparticles known as g-r noise. These noise concerns have so far precluded MKIDs use in CMB measurements. However, I have shown that for reasonable QUBIC conditions a total NEP (photon + g-r noise added in quadrature) of ~20% greater than the photon noise limit can be achieved for an aluminum resonator of reasonable dimensions. This is moderately better than the TESs under equivalent conditions. The key objectives of my proposed research will be to identify which detector technology is best suited for use in QUBIC and to design, fabricate, test and install a 900-element detector array. Fabricating

Project Image Detectors for Measurements of the Cosmic Microwave Background Radiation

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Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Responsible Program:

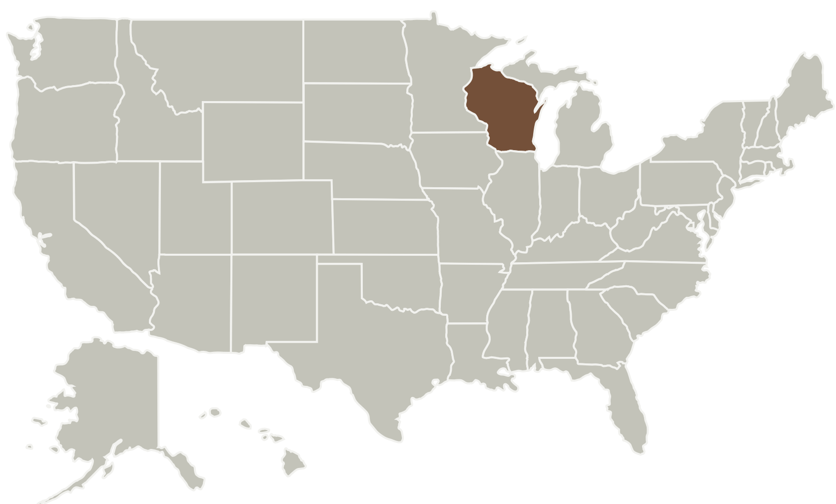
Space Technology Research Grants

TESs or MKIDs, however, requires a high-level clean room with dedicated equipment for superconducting thin-film deposition to which I do not have access at my home institution. The NSTR Fellowship would allow me to work with scientists at Goddard Space Flight Centers Detector Development Lab or the Jet Propulsion Laboratory's Microdevices Lab, groups which are currently world leaders in cryogenic detector research and among the few groups worldwide having significant experience with TESs and MKIDs. Their expertise and facilities will be invaluable in the array design and fabrication process.

Anticipated Benefits

This project aims to identify which detector technology is best suited for use in the Q&U Bolometric Interferometer for Cosmology (QUBIC) and to design, fabricate, test and install a 900-element detector array. QUBIC is a novel ground-based telescope for detecting B-mode polarization anisotropies in the Cosmic Microwave Background.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
University of Wisconsin-Madison	Supporting Organization	Academia	Madison, Wisconsin

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

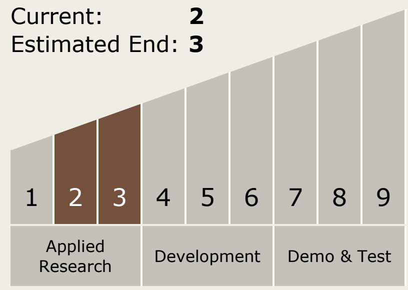
Peter Timbie

Co-Investigator:

Amy E Lowitz

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**



Technology Areas

Primary:

- TX08 Sensors and Instruments
  └ TX08.1 Remote Sensing Instruments/Sensors
    └ TX08.1.1 Detectors and Focal Planes

Primary U.S. Work Locations

Wisconsin

Images

11521-1363176954759.jpg
Project Image Detectors for Measurements of the Cosmic Microwave Background Radiation
(https://techport.nasa.gov/image/1741)

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html